

## IN THE SPECIFICATION:

Please replace paragraphs [0002], [0026], [0029], [0030], [0032], [0033], [0035], and [0036] with the following amended paragraphs:

**[0002]** The invention is useful in forming grooves used in the system described in ~~[[the]] U.S. Patent Application Serial No. 09/699,203~~ 6,524,451 filed October 26, 2000 by Dustin A. Cochran entitled "Dual Conical ECM Grooving Device" (Attorney Docket No. A-69689). This ~~application~~ patent is incorporated herein by reference.

**[0026]** Fig. 2 is a vertical sectional view of a hub 200 supported by dual conical and journal ~~bearing 200~~ bearings for rotation about a shaft (not shown). The hub 200 ~~included in 201~~ is integrated with the sleeve whose internal surfaces define the grooves which form the hydrodynamic bearing which supports the hub 200 for rotation. As is well-known in this technology, a shaft (not shown) is inserted within the hub 200 and has dual conical surfaces which face the conical regions 210, 212 at the upper and lower ends of the bearing region. The shaft would further include a smooth center section which would cooperate with the journal bearings defined by the grooved regions 214, 216. As is well-known in this field of fluid dynamic bearings, fluid will fill the gap between the stationary shaft and the inner grooved surfaces of the sleeve. As the sleeve rotates, under the impetus of interaction between magnets mounted on an inner surface of the hub which cooperate with windings supported from the base of the hub, pressure is built up in each of the grooved regions. In this way, the shaft easily supports the hub 200 and disc 202 for constant high speed rotation.

**[0029]** The apparatus for forming grooves using ECM is shown especially in Fig. 3. The work piece of Fig. 2 is placed within the frame 300; as can be seen the frame 300 is configured to define a cavity 302 which has a pair of electrodes 304 running through the center. When the work piece 200 is placed in the cavity 302, it is generally held firmly in place within the edges of the framing pieces 306. The electrodes 304, which are axially movable along axis 310, each include both a conical region 312 which will cooperate

with the internal ~~cone~~ cones 210 and 212 of the hub 200, and a journal region 314 extending from a narrow end of the conical ~~electrode~~ region which will cooperate with the internal ~~hub 210 and sleeve 214~~ journals 240 and 242, respectively.

**[0030]** When the work piece 200 is in place in the frame 300, the electrodes 304 are moved back and forth along the axis 310 until the gap between each electrode and the facing surface of the work piece is established. It can be seen, as generally represented in the figure, that each of the electrodes 304 carries the pattern which is to be imposed on the inner surface of the conical 210, 212 and journal region regions 214, 216 of the work piece 200. It is also readily apparent that the problem remaining is to accurately set the gap, which must be measured in microns, between the movable electrodes and the work piece 200 which is being held in place in the frame, and to do so quickly and repetitively on a high speed basis. According to the present invention, this measurement can be achieved before the electric current is turned on, by beginning to pump electrolyte through the electrolyte inlet 320. The electrolyte will move through this inlet and the inlet channel 322 and pass between the interior of the work piece or hub 200 and the exterior of the ~~electrolyte~~ electrode 304, to exit through the exit channel 324 and exit 326. It should, of course, be apparent that the direction of flow is arbitrary. To check the setting of the gap between the electrode and the interior of the work piece, a mass flow measurement device 330 of a type well-known in this field is used. This mass flow measurement device is precalibrated in units to a specific number which represents the setting of the gap. In other words, the ~~electrode~~ electrode/work piece gap is a critical orifice. According to the method practiced herein, electrolyte at a static fixed pressure (which preferably for ease of use is always the same) is applied to the inlet 320 and the inlet gap 322. As the gap between the electrode 304 and the work piece 200 is modified by moving the electrodes, the mass flow measurement will change. By always adjusting the mass flow measurement to a critical target number, the same gap is always defined between the electrode and the work piece surface. Obviously, this method is especially applicable to defining the gap between an electrode conical surface and a work flow conical surface.

**[0032]** The ECM process can then be executed by then applying an electrical potential to the work piece and electrode, the work piece receiving the positive potential and the electrode serving as the cathode and receiving the negative potential. By timing the current flow, an imprint in the form of the groove pattern shown in Fig. 2 is placed on the work piece. As is well-known, the width and depth of the resulting grooves is controlled by the duration and level of current applied to the work piece 200 and the cathode 304. The current level being modified primarily by the gap which has now been carefully adjusted by other electrolyte ~~perimeters~~ parameters.

**[0033]** The axially axial adjustment of the electrodes 304 is achieved preferably by a worm and gear arrangement 350 shown at either end of the frame and of a type well-known in this technology. Such worm and gear arrangements are capable of precise axially axial movement of the electrodes and, if desired, can be easily gang coupled together.

**[0035]** Fig. 4 illustrates a modification to the above described method which allows the simultaneous grooving of two different regions to two different depths. Referring specifically to Fig. 4, in this figure we see a method and apparatus for grooving both a cylindrical region 410 and a conical region 412 simultaneously. As described above, and is known from the prior art, the cylindrical region 410 will form the pumping region of a grooved pumping seal; and the conical region 412 will form the grooves ~~where the~~ 214, 216 of a conical hydrodynamic bearing. In order ~~which~~ to achieve the grooving on the inner surfaces of the sleeve 414 which is shown in this figure, a dual element/voltage electrode generally indicated at 415 is utilized. In this electrode 415, the outer electrode is a cylindrical electrode 418 which terminates in a conical region 420 which will face the region towards the inner surface of the sleeve 412 which is to have the grooves which form the conical bearing. A second rod like element 422 is placed inside the cylindrical electrode element 418 and extends beyond the end of the conical working region 420. The end of the rod like electrode element 426 has a groove design which will serve as the working electrode to form the grooves on the inner surface of the pumping region 410 for the grooved pumping seal. The dual electrode

~~element 428~~ elements 418 and 422 are separated one from the other by insulator regions 428 and ~~430~~ 429. The insulator may comprise a plurality of separate insulator regions as shown, or one continuous insulator. In operation ~~Operation~~, the dual element electrode 415 is inserted into alignment with the pumping seal region 410 and conical seal region 412 of the sleeve 14. This insertion of alignment may be accomplished using the apparatus of Fig. 3 described above or other apparatus as long as the necessary alignment is achieved. In a typical grooved pumping seal and conical seal design, the pumping region 410 has a groove depth which is about twice as great the conical region 412. Therefore, each of the electrode elements 418 and 422 should be operated at a different voltage. The rate of material removal is roughly linear function of the voltage applied to the electrode, all other elements of the system being substantially the same. Therefore, a dual voltage power supply will be provided which is capable of supplying different voltages to the two electrodes 418, 422. This dual voltage power supply could be achieved in a number of ways which would be apparent to a person of skill in this field; for example, it could be simply be two separate power supplies making up the power supply 430, with separate outputs to the cylindrical element 418 and the rod element 422. Alternatively, a single power supply could be used, with a high current resistor coupling the output to the conical cylindrical element 418 in order to reduce the voltage by a proportionate amount. Typical operating voltages would be to supply the rod like element which grooves the pumping region with a voltage of about 4 volts, and then provide the cylindrical element 418 with a voltage of about 2 volts. The process described above with respect to Fig. 3 could then be executed. ~~With the~~ The material being will be removed for a measured period of time in order to achieve the desired groove depth of about .015 mm ~~and then~~ in the pumping region 410 and a groove depth of about .007 mm ~~and then~~ in the conical region.

**[0036]** If ~~these~~ the system of Fig. 3 is being used, it can be seen that it is desirable to simultaneously groove both the conical region 412 ~~and in~~ and a similar similarly configured conical region 440 at the opposite end of a sleeve, as well as both the pumping region 410 and a similarly configured pumping region 442 at the opposite end. In this case, a combination of cylindrical and rod like electrodes could be simultaneously

introduced from the opposite end, with the ends of these rod like elements separated by the insulator 340 which is shown most clearly in Fig. 3.